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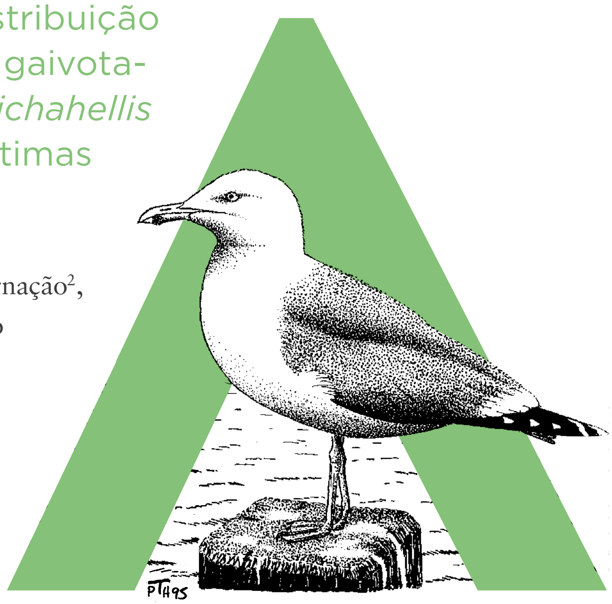
Changes in numbers and distribution of Yellow-legged Gull *Larus michahellis* nesting in Portugal during the last two decades

Alterações no tamanho e distribuição da população nidificante de gaivota-de-patas-amarelas *Larus michahellis* em Portugal ao longo das últimas duas décadas



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ABSTRACT

Over the last decades, the population size and breeding range of several gull species have increased worldwide. The unlimited amount of food of anthropogenic origin is thought to be the main vector for such increase. In Portugal, the Yellow-legged Gull *Larus michahellis* is the most abundant breeding gull species. There is some evidence of an expansion of this species in mainland Portugal since the 1990s, but no up-to-date data is available. During the breeding season of 2021-2022, a national census was performed. Data on potential anthropogenic food sources was gathered in order to assess the effect of commercial fishing, urban residues and landfills on the numbers of Yellow-legged Gulls. It is estimated that 7,350 to 8,000 pairs breed in Portugal along all mainland coast and nearly on all islands and islets. Despite the sharp decline in the population on Berlenga Island, the largest breeding colony in the country, due to long-term population control, the remaining mainland population is experiencing an increase in both size and breeding distribution. Approximately 30% of the mainland population was found to breed in urban areas. Conversely, the gull population in Madeira has decreased approximately 98% compared to the last census, in 2002. In the Azores, the population appears to be decreasing, which should be confirmed in future monitoring. Decrease in Madeira and Azores are likely mainly explained by a reduction in food availability following the closure of several landfills. At a national scale, higher numbers of gulls were found near fishing harbours and in municipalities where the amount of urban waste is higher. Our results suggest that an improvement on both the management of fish discards/offal and waste treatment in order to reduce food subsidiaries for Yellow-legged Gulls will affect the size of the breeding population.

Keywords: Fisheries discards, landfill, Azores, Madeira, Selvagens, urban gulls, urban residual management

RESUMO

Várias espécies de gaivotas aumentaram a nível global em termos de número e distribuição ao longo das últimas décadas. O alimento de origem antropogénica ilimitado é apontado com o principal fator para este aumento. Em Portugal, a gaivota-de-patas-amarelas *Larus michahellis* é a espécie de gaivota nidificante mais abundante. Existem algumas evidências da sua expansão em Portugal Continental a partir dos anos 1990, apesar da ausência de informação atual. Um censo nacional teve lugar durante a época reprodutora de 2021-2022. Foram recolhidos dados das potenciais fontes de alimentação antropogénica para avaliar o efeito da pesca comercial, resíduos urbanos e aterros sanitários nos números de gaivota-de-patas-amarelas. A população nacional foi estimada em 7.350 – 8.000 casais reprodutores, distribuindo-se ao longo de toda a costa continental e praticamente em todas as ilhas e ilhéus. Apesar da redução acentuada no tamanho da população da ilha da Berlenga, a maior colónia reprodutora do país, devido a um controlo populacional de longo termo, a população continental sofreu um ligeiro aumento em termos de tamanho e uma expansão acentuada na distribuição das áreas de reprodução. Aproximadamente 30% da população continental reproduz-se em áreas urbanas. Por outro lado, a população da Madeira sofreu um decréscimo de aproximadamente 98% quando comparada com o censo realizado em 2002. Nos Açores, a população nidificante aparenta estar em regressão, o que deverá ser confirmado futuramente. O decréscimo nestas regiões foi principalmente explicado pela redução de alimento após o encerramento de vários aterros. À escala nacional, o número de casais reprodutores foi maior nas zonas próximas a portos de pesca e onde a quantidade de resíduos urbanos produzida foi maior, apontando para que uma melhoria nos sistemas de gestão destas atividades, com o intuito de reduzir as oportunidades de alimento para a gaivota-de-patas-amarelas, irá afetar o tamanho da população reprodutora.

Palavras-chave: Rejeições de pesca, aterro, Açores, Madeira, Selvagens, gaivotas urbanas, gestão de resíduos urbanos

Introduction

Over the last decades, several populations of large gulls belonging to the genus Larus have increased in size and expanded their range, including the Yellow-legged Gull *Larus michahellis* (Belant 1997, Morais et al. 1998, Vidal et al. 1998, Ross-Smith et al. 2014, Huig et al. 2016, Winton and River 2017). The fast increase in food availability originating from human related activities is considered one of the main reasons for the current trend of large gulls (Duhem et al. 2008). Such sources of food include landfills, fisheries discards and urban sites (Pierre et al. 2010, Calado et al. 2018, 2020b, Romero et al. 2019, Lopes et al. 2021).

Portugal harbours around 5% of the Yellow-legged Gull population nesting in Europe (Equipa-Atlas 2008, BirdLife International 2021). However, only occasional information on breeding numbers and historical data are available at the national level. In the case of Portugal mainland, the last census of breeding pairs covering the entire rocky coast took place in 2002 (Catry 2002, Morais et al. 2010), followed only by occasional counts aiming at specific colonies. Berlenga Island colony is the one with more detailed information, where yearly counts have been made during the breeding season since 1977 (Morais et al. 2016). In the case of the Azores, the Madeira and the Selvagens archipelagos, available information on the overall breeding population size is dated from the earlies 2000 (Neves et al. 2006, Equipa-Atlas 2008), although some occasional counts have been performed more recently in the Madeira and the Selvagens archipelagos (e.g. Catry et al. 2010, IFCN 2020).

The main objectives of the present study were (1) to gather updated information on the size and distribution of the breeding population of the Yellow-legged Gull in Portugal, (2) to assess the population trend between 2002-2004 and 2021 and (3) to discuss the main causes for potential changes in terms of breeding numbers. We expect Yellow-legged Gulls to have expanded their breeding range mainly to areas where anthropogenic food is more available. Furthermore, an increase of the total population at national level is expected, although some fluctuations in some specific areas where gulls were historically breeding, may occur.

Methods

Study area

This study was conducted in Portugal, including the mainland and the archipelagos of the Azores, Madeira and Selvagens (Fig. 1). Berlengas archipelago, located approximately 11 km off the coast, was considered as part of Portugal mainland (Fig. 1, code number 8). Surveyed areas included all sites where breeding colonies were known or suspected. In the case of the mainland, the entire coast was prospected, including natural and urban sites. In the case of the archipelagos, the entire coast of each island or islet was prospected by boat or on foot.

Figure 1- Distribution of Yellow-legged Gull (*Larus michahellis*) nesting sites (black dots) in Portugal mainland and the Azores, Madeira and Selvagens archipelagos. The locations of landfills (brown triangles) and fishing harbours (blue triangles) are also indicated. Code numbers are indicated in Table 1.

Figura 1 - Distribuição dos locais de nidificação (pontos pretos) de gaivota-de-patas-amarelas (*Larus michahellis*) em Portugal continental e nos arquipélagos dos Açores, da Madeira e das Selvagens. As localizações dos aterros sanitários (triângulos castanhos) e dos portos de pesca (triângulos azuis) são também indicadas. A descrição da numeração apresentada é indicada na tabela 1.

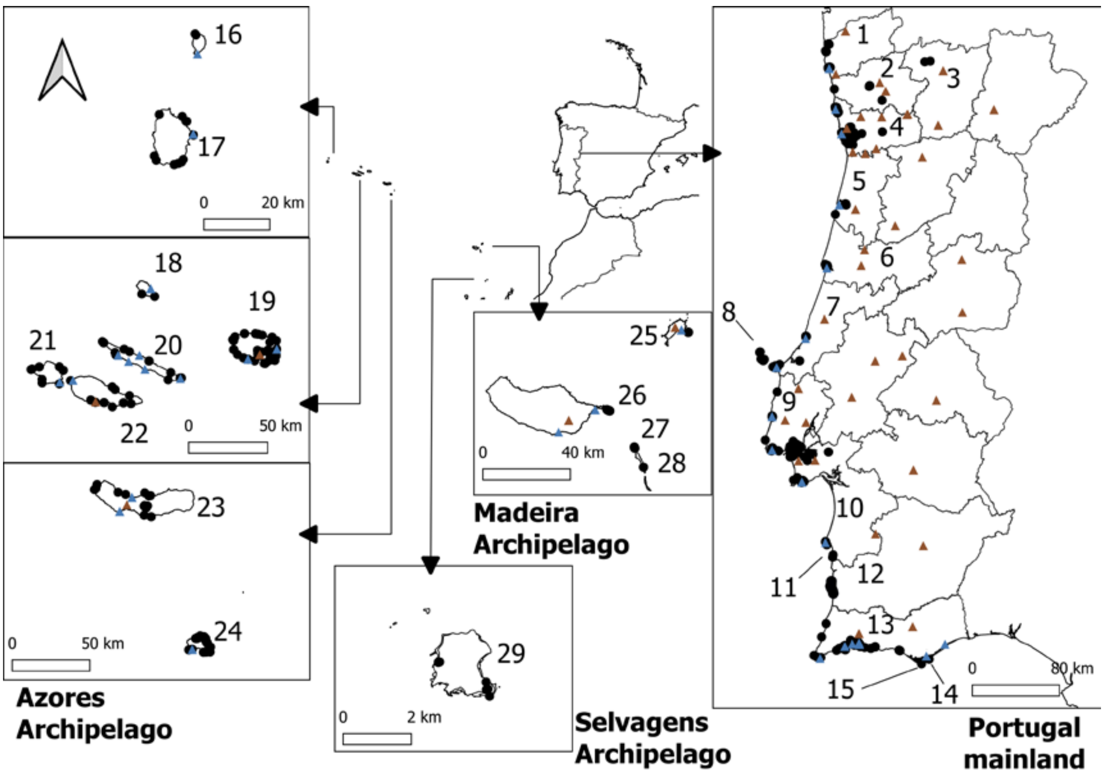

Table 1 - Number of confirmed, likely and potential breeding pairs of Yellow-legged Gull (*Larus michahellis*) recorded in Portugal in 2021-2022. The population estimate is given by the sum of confirmed, likely and potential pairs. Numbers are presented for each region by municipality or main island/colony. Habitat description was recorded as island/islet (I), cliff (C), inland lake (L) and urban (U). Some sites presented nests in more than one type of habitat. Nests were counted directly (N) or estimated from the number of adult gulls recorded (A; see methodology for further details). Habitat description and count method categories are ordered by total number of nests/pairs recorded at each site. * highlights districts/islands where population size was not estimated due to a lack of coverage.

Tabela 1 - Número de casais de gaivota-de-patas-amarelas (*Larus michahellis*) registados como confirmados, possíveis e potenciais no decorrer do censo em Portugal em 2021-2022. A estimativa populacional é dada como somatório do número de casais confirmados, possíveis e potenciais. São apresentados os valores para cada município ou ilha/colónia em cada região. O habitat foi caracterizado como ilha/ilhéu (I), falésia (C), lago (L) e urbano (U). Alguns locais apresentaram ninhos em mais do que um tipo de habitat. Os ninhos foram contados diretamente (N) ou estimados a partir do número de gaivotas adultas observadas (A; ver metodologia para mais detalhes). As categorias de descrição de habitat e método de contagem são ordenadas pelo número total de ninhos/casais registados em cada local. O * indica os distritos/ilhas onde a estimativa populacional não é apresentada por falta de cobertura do censo.

Code	District/Island	Habitat description	Count method	Confirmed pairs	Likely pairs	Potential pairs	Population estimate (breeding pairs)
	Mainland						
1	*Viana do Castelo*	U	N, A	54	4	0	54 –58
2	*Braga*	U	A, N	4	0	6	4 –10
3	*Vila Real*	I	N, A	1	1	0	1 -2
4	*Porto*	U	N, A	593	200	20	593 –813
5	*Aveiro*	U	A	0	2	1	0 –3
6	*Coimbra*	U	N, A	19	1	7	19 –27
7	*Leiria excluding Berlengas archipelago*	U	A, N	187	50	30	187 –267
8	*Berlengas archipelago*	I	A, N	2,397	0	0	2,397
9	*Lisboa*	U, C	N, A	203	16	17	203 –236
10	*Setúbal excluding Pessegueiro Island*	U, C	N, A	321	18	17	321 – 356
11	*Pessegueiro Island*	I	N	860	40	0	860 - 900
12	*Beja*	C	N, A	17	0	6	17 - 23
13	*Faro excluding islands*	U, C, I	A, N	368	33	54	368 – 455
14	*Culatra Island*	I	N	57	0	0	57
15	*Barreta Island*	I	N	485	0	0	485
	Azores						
16	*Corvo*	I, C	N	41	0	0	41
17	*Flores*	I, C	A, N	6	39	0	44-45

Code	District/Island	Habitat description	Count method	Confirmed pairs	Likely pairs	Potential pairs	Population estimate (breeding pairs)
18	*Graciosa*	I, C	N, A	46	0	20	46-66
19	*Terceira*	I, C	A, N	590	0	23	590-613
20	*São Jorge*	I, C	A	0	77	0	*
21	*Faial*	I, C	A, N	45	0	0	*
22	Pico	I, C	A, N	104	1	57	104-162
23	*São Miguel*	I, C, L	N, A	497	169	22	688
24	*Santa Maria*	I, C	N, A	93	0	5	93-97
	Madeira						
25	*Porto Santo – Cima Islet*	I	A, N	7	0	39	7-46
26	*Desembarcadouro Islet*	I	N	37	0	0	37
27	*Chão Islet*	I	N, A	7	0	3	7 - 10
28	*Deserta Grande*	I	N, A	1	0	5	1-6
	Selvagens						
29	*Selvagem Grande*	I	A	0	6	0	0-6

Breeding population census

Counts were carried out mainly in May 2021 when Yellow-legged Gulls are expected to be incubating their eggs. Some additional data was also collected in June and July at the urban sites during chick rearing, allowing to confirm less conspicuous nests. Also, two sites that were not prospected in 2021 were prospected in May 2022, namely the coasts of Cabo da Roca (Lisbon) and Odemira (Beja). Whenever possible, all nests were individually counted. If breeding was confirmed but total nest counting was not possible due to logistical constraints (e.g. in less accessible areas), counts were targeted at birds in full adult plumage. A nest was assumed to be confirmed when one adult gull was observed in incubation position, or when a nest was observed to contain at least one egg or chick. Further evidence of nesting, such as territorial calls and restless/aggressive behaviour of one or more adult individuals (classified as likely breeder), or a single gull or pair present in a known nesting habitat (classified as potential breeder), was also recorded and included in the counts. In such cases, the number of breeding pairs was assumed to be the number of counted birds divided by two and rounded up, i.e. a count of two birds was considered as one breeding pair and a count of three birds was considered as two pairs. The coordinates of all individual nests, groups of nests, adult birds, and group of adult birds were recorded.

Anthropogenic food sources

Data on three potential food sources were used to assess their effect on Yellow-legged Gull breeding population size. The annual weight of residues delivered from 2015 to 2020 to each active landfill was used as a proxy for available food from the landfill. Data from mainland, Azores and Madeira landfills were collected from https://apambiente.pt/residuos/dados-sobre-residuos-urbanos (published by the Portuguese Environment Agency), http://www.azores.gov.pt/gra/srrn-residuos (published by the Azorean Regional Government) and http://www.aguasdamadeira.pt/Aempresa/Documenta%C3%A7%C3%A3o.aspx (published by ARM – Águas e Resíduos da Madeira S.A.), respectively. The annual weight of non-differentiated residues collected per municipality from 2002 to 2020 (accessible at https://www.pordata.pt/Municipios/Res%c3%adduos+urbanos+total+e+por+tipo+de+recolha-655) was used as proxy for available food in urban sites. The amount of fish landed in the main fishing harbours in Portugal from 2002 to 2020 (data accessible on the national fisheries statistics website (https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_publicacoes&PUBLICACOEStipo=ea&PUBLICACOEScoleccao=107656&selTab=tab0&xlang=pt) was used as proxy for food availability originating from commercial fisheries.

Data analyses

The number of breeding pairs was quantified for each municipality as the sum of confirmed, likely and potential number of pairs. This approach allowed for a simple definition of population units. General linear models with a negative binomial error distribution were used to evaluate the effect of anthropogenic food sources on the number of breeding pairs counted in 2021. The function "glm.nb", of the MASS package v.7.3-51.4 (Venables and Ripley 2002) implemented in R v.3.6.1 (R Core Team 2021) was used for this purpose. Due to the culling programme that has been implemented on the Berlengas archipelago from 1994 onwards (Morais et al. 2016) as well as in Lagoa do Fogo and Vila Franca Islet colonies (in the Azores), those sites were removed from the analysis. Given that the last more complete census of Yellow-legged Gull in Portugal is dated from 2002-2004, we used data on anthropogenic food sources from 2002 onwards, assuming that the changes in population numbers might be reflected by changes in anthropogenic food availability. Variables included in the model as predictors comprised the mean distance between the location of all nests in a given municipality (calculated as the centroid of all nest locations) and the nearest landfill (hereafter referred to as distance to landfill), the mean distance between the location of all nests in a given municipality and the nearest fishing harbour (hereafter referred to as distance to harbour), the mean weight of residues delivered to the nearest landfill (hereafter referred to as landfill deliveries), the mean weight of non-differentiated residues collected in a given municipality (hereafter referred as urban residues) and the amount of fish landed in the nearest fishing harbour (hereafter referred to as fish landings; table S1). Given that Yellow-legged Gulls are somewhat limited in terms of movements during the nesting period, but can nonetheless fly dozens of kilometres to feed (Ceia et al. 2014, Matos et al. 2018), two additional predictors were estimated as the mean weight of residues delivered to all landfills located within a radius of 35 km from the nest locations (hereafter referred as landfill deliveries <35 km) and the mean weight of fish landed in all fishing harbours located within a radius of 35 km from the nest locations (hereafter referred as fish landings <35 km). The factor "region" as mainland vs Azores, Madeira and Selvagens archipelagos was included in the model in order to control for differences among regions. Finally, the annual growth rate of the Yellow-legged population breeding in each municipality, compared to historical data (see Table 3), was estimated. The instantaneous growth rate (*r*) was calculated as a function of annual number of breeding pairs at outset (N_0), and number of breeding pairs after *t* years (N_t). The annual multiplication rate (γ) was estimated as an exponential function of r. The annual growth rate (%) was expressed as (γ-1) x 100.

$$r = \frac{lnNt - lnN0}{t} \qquad y = e^{r}$$

Interactions between region and all the other variables were also included due to the expected difference on both management and magnitude of landfill deliveries, urban residues and fishery landings. Variables were excluded using a backward stepwise approach from the full model. The fitting of the selected model and the contribution of each variable to the model were evaluated by analysing residual deviance and degrees of freedom using a Chi-squared test. Statistical significance was assigned to $p < 0.05$.

Table 3 - Estimativa do número de casais reprodutores de gaivota-de-patas-amarelas (*Larus michahellis*) em Portugal no passado e presente. A tendência do tamanho da população é dada para cada região/distrito como em crescimento (↗), decréscimo (↘), estável (≈) ou desconhecida (?). Informação mais detalhada sobre a localização das colónias açorianas pode ser consultada em Neves et al. (2006). O * indica os distritos/ilhas onde não ocorreram contagens.

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Region/District	Site	Estimated pairs		Trend	Year of historical data (Source)
		Historical	This study		
MAINLAND				↘	
Beja	*SW coast*	103	17 - 23	↘	2002 (Catry 2002)
Faro	*Culatra Island*	0	57	↗	1976 – 1980 (Araújo and Rufino 1981)
	Barreta Island	0	485	↗	1976 – 1980 (Araújo and Rufino 1981)
	Sotavento Algarvio	529 – 554	367 - 453	↘	2002 (Catry 2002)
	Lagos	300 – 400	13 - 66	↘	2010 (STRIX 2010)
Lisboa	*Cabo da Roca*	85	*		2002 (Catry 2002)
	Lisboa, Algés e Oeiras	125	182 - 193	↗	2016-2017 (Mãe-D'Água 2017)
Leiria	*Berlenga Island*	12,043	2,397	↘	2002 (Morais et al. 2010)
	Peniche	232	181 - 260	≈	2007 (Bastos 2007)
Setúbal	*Espichel/Arrábida*	51	*		2002 (Catry 2002)
	Pessegueiro Island	175 – 200	860 - 900	↗	2002 (Catry 2002)
Porto	*Área Metropolitana do Porto*	34	593 - 813	↗	2010 (CIIMAR 2011)

Region/District	Site	Estimated pairs		Trend	Year of historical data (Source)
		Historical	This study		
AZORES				?	
Corvo	*Ponta do Marco Islet*	*	2		1984 (Neves et al. 2006)
	Ponta do Marco	90	39	↘	
Faial	*Costa dos Espalhafatos*	25	25	≈	2004 (Neves et al. 2006)
	Costa da Nau (N Capelinhos)	125	*		2004 (Neves et al. 2006)
	Vulcão dos Capelinhos	160	*		2004 (Neves et al. 2006)
	Baía do Varadouro	150	*		2004 (Neves et al. 2006)
	Morro de Castelo Branco	20	*		2004 (Neves et al. 2006)
	Monte da Guia	0	20	↗	2004 (Neves et al. 2006)
Flores	*Maria Vaz Islet*	86	8	↘	2004 (Neves et al. 2006)
	Cartário Islet	32	6	↘	2004 (Neves et al. 2006)
	Álvaro Rodrigues Islet	42	24	↘	2004 (Neves et al. 2006)
	Muda Islet	5	0	↘	2004 (Neves et al. 2006)
	Ponta Furada	1	*		2004 (Neves et al. 2006)
	Fajã Lopo Vaz	0	3 – 4	↗	2004 (Neves et al. 2006)
	Ponta da Baixa Rasa	0	3	↗	2004 (Neves et al. 2006)
Graciosa	*Baixo Islet*	320	46 - 66	↘	2004 (Neves et al. 2006)
	Ponta Branca	0	0 - 20	≈	2004 (Neves et al. 2006)
Pico	*Ponta do Espigão*	50	27	↘	2004 (Neves et al. 2006)
	Mistério da Prainha	380	64 – 100	↘	2004 (Neves et al. 2006)
	Madalena Islets	53	16	↘	2004 (Neves et al. 2006)
	Castelete	0	1	≈	2004 (Neves et al. 2006)

Region/District	Site	Estimated pairs		Trend	Year of historical data (Source)
		Historical	This study		
Pico	*Foros*	0	1	≈	2004 (Neves et al. 2006)
	Escamiro Islet	0	2 – 3	↗	2004 (Neves et al. 2006)
	Pontas Negras	0	8	↗	2004 (Neves et al. 2006)
	Silveira	0	2	↗	2004 (Neves et al. 2006)
	Terra do Pão	0	1 – 4	↗	2004 (Neves et al. 2006)
Santa Maria	*Lagoínhas Islet*	95	43	↘	2004 (Neves et al. 2006)
	Vila Islet	1	1	≈	2004 (Neves et al. 2006)
	From Ponta Norte to Ponta dos Matos (excluding Lagoinhas Islet)	0	24	↗	2004 (Neves et al. 2006)
	From Ponta Negra to Ponta do Cedro (including São Lourenço islets)	0	14 - 15	↗	2004 (Neves et al. 2006)
	From Ponta da Malbusta to Ponta do Castelete	0	11 - 14	↗	2004 (Neves et al. 2006)
São Jorge	*Topo Islet*	730	*		2004 (Neves et al. 2006)
	Ponta dos Rosais	250	23	↘	2004 (Neves et al. 2006)
	Morro do Lemos	0	*		2004 (Neves et al. 2006)
	Fajã do Cardoso	*	*		2004 (Neves et al. 2006)
	Fajã do Nortezinho	*	*		2004 (Neves et al. 2006)
	Fajã da Betesga	0	5	↗	2004 (Neves et al. 2006)
	Fajã Vasco Martins	0	30	↗	2004 (Neves et al. 2006)
	Fajazinha	0	6	↗	2004 (Neves et al. 2006)
	Morro Grande	0	10	↗	2004 (Neves et al. 2006)
	Pico dos cutelos	0	2	↗	2004 (Neves et al. 2006)
	Ponta Furada	0	1	≈	2004 (Neves et al. 2006)

Region/District	Site	Estimated pairs		Trend	Year of historical data (Source)
		Historical	This study		
São Miguel	*Mosteiros*	115	109	≈	2004 (Neves et al. 2006)
	Ponta do Escalvado	40	60	↗	2004 (Neves et al. 2006)
	North of Ponta da Ferraria	60	*		2004 (Neves et al. 2006)
	Ladeira da Velha (Miradouro de Santa Iria)	1	*		2004 (Neves et al. 2006)
	Praia dos Moinhos	2	*		2004 (Neves et al. 2006)
	Lagoa do Fogo	600	433	↘	2004 (Neves et al. 2006)
	Porto da Caloura	2	*		2004 (Neves et al. 2006)
	Ponta do Ermo	0	9	↗	2004 (Neves et al. 2006)
	Fenais da Luz	0	5	↗	2004 (Neves et al. 2006)
	Morro das Capelas	0	8	↗	2004 (Neves et al. 2006)
	Vila Franca do Campo Islet	0	64	↗	2004 (Neves et al. 2006)
Terceira	*Quatro Ribeiras*	10	17 - 20	↗	2004 (Neves et al. 2006)
	Ponta do Raminho	36	22	↘	2004 (Neves et al. 2006)
	Ponta da Serreta	3	6 - 8	↗	2004 (Neves et al. 2006)
	Ponta da Rubra (South Serreta)	65	37 – 39	↘	2004 (Neves et al. 2006)
	Monte Brasil	50	15 - 18	↘	2004 (Neves et al. 2006)
	Cabras Islet W	350	212	↘	2004 (Neves et al. 2006)
	Cabras Islet E	390	232	↘	2004 (Neves et al. 2006)
	Agualva	0	1 – 2	≈	2004 (Neves et al. 2006)
	Altares	0	7	↗	2004 (Neves et al. 2006)
	Caldeira do Guilherme	0	0 – 10		2004 (Neves et al. 2006)
	Doze Ribeiras	0	10	↗	2004 (Neves et al. 2006)

Region/District	Site	Estimated pairs		Trend	Year of historical data (Source)
		Historical	This study		
Terceira	*Contenda Islet*	0	2 – 3	↗	2004 (Neves et al. 2006)
	Lajes	0	18 - 20	↗	2004 (Neves et al. 2006)
	Santa Bárbara	0	3 - 5	↗	2004 (Neves et al. 2006)
	São Bartolomeu	0	2	↗	2004 (Neves et al. 2006)
MADEIRA				↘	
Madeira	*Desembarcadouro Islet*	1,650	37	↘	2002 (Fagundes et al. 2002)
	Deserta Grande	0	1 – 6	↗	2002 (Fagundes et al. 2002)
	Chão Islet	700	7 - 10	↘	2002 (Fagundes et al. 2002)
Porto Santo	*Cima Islet*	400	7 - 46	↘	2002 (Fagundes et al. 2002)
	Ferro Islet	200	*		2002 (Fagundes et al. 2002)
	Cal Islet	1,000	*		2002 (Fagundes et al. 2002)
SELVAGENS				?	
Selvagem Grande		12	0 - 6	↘	2007 (Matias and Catry 2010)
Selvagem Pequena		6 – 7	*		2010 (Catry et al. 2010)
Ilhéu de fora		1 – 4	*		2010 (Catry et al. 2010)

Results

Population size and distribution of breeding colonies

A total of 7,033 Yellow-legged Gull breeding pairs were counted in Portugal, including the Azores, the Madeira and the Selvagens archipelagos. In addition, 657 likely and 329 potential breeding pairs were recorded (Table 1). Berlenga Island held the largest colony of Portugal with 2,397 pairs, representing 30 to 34% of the national breeding population and 40 to 43% considering only the mainland region. The second largest colony was found in Pessegueiro Island with 860 to 900 breeding pairs. The third colony in terms of number of breeding pairs, and representing the main urban colony, was recorded in Porto district (593 – 813 breeding pairs), occupying a large portion of the coastal municipalities of this district, including Gondomar, Maia, Matosinhos, Penafiel, Porto, Póvoa de Varzim, Valongo, Vila do Conde and Vila Nova de Gaia. In fact, approximately 30% of the mainland population was found to breed in urban areas (1482-1943 pairs), and all birds north of Lisbon, excluding Berlengas and Pisão dam (in Vila Real), were nesting in urban sites. In terms of distribution, Yellow-legged Gulls were found to breed along the entire coastline of the continental region, from Caminha (Viana do Castelo district) to Culatra Island (Faro district).

In the Azores archipelago, São Miguel and Terceira islands held the biggest breeding colonies of the species, with 688 and 590 to 613 breeding pairs, respectively. The species was found on all main islands and on the larger islets. No birds were confirmed to breed in urban areas, except for one breeding attempt recorded on the roof of a house in Ribeira Grande, on São Miguel Island.

In the Madeira archipelago, small numbers of breeding Yellow-legged Gulls were recorded. The main colonies were recorded on Cima Islet (located off Porto Santo Island) and Desembarcadouro Islet (located off Madeira Island) with 7 to 46 and 37 breeding pairs, respectively. Besides those, breeding was only recorded on Deserta Grande (1 - 6 pairs), Chão Islet (7 -10 pairs) and Selvagem Grande (0 – 6 pairs). No data was collected on Ferro and Cal islets (located off Porto Santo) and Selvagem Pequena Island.

The effect of anthropogenic food sources on gull numbers

The number of breeding pairs in each municipality was explained by distance to harbour, urban residues, landfill deliveries (<35 km), Yellow-legged Gull growth rate and the two-way interactions between region and landfill deliveries (<35 km) and the final model explained 63% of the number of breeding pairs of Yellow-legged Gulls (Table 2). A Goodness-of-Fit (GOF) test indicated that the negative binomial model fitted our data well ($p = 0.08$). Distance to harbour (-0.06 ± 0.01, mean ± standard error) showed a negative effect on the number of Yellow-legged Gull breeding pairs, i.e. numbers were higher where harbours were closer. Urban residues (0.02 ± 0.01) and growth rate (0.11 ± 0.03) showed a positive effect (Fig. 2; all $p < 0.05$), i.e. higher number of breeding pairs were recorded in municipalities with higher amount of annual urban residues and with more positive gull growth rates. Although region by itself did not have a significant effect, the landfill deliveries (<35 km) had a positive effect on the number of breeding pairs of Azores and Madeira archipelagos (0.07 ± 0.03; $p < 0.05$), pointing to higher numbers of Yellow-legged Gulls in those municipalities with higher deliveries in those landfills located <35 km apart from the colonies.

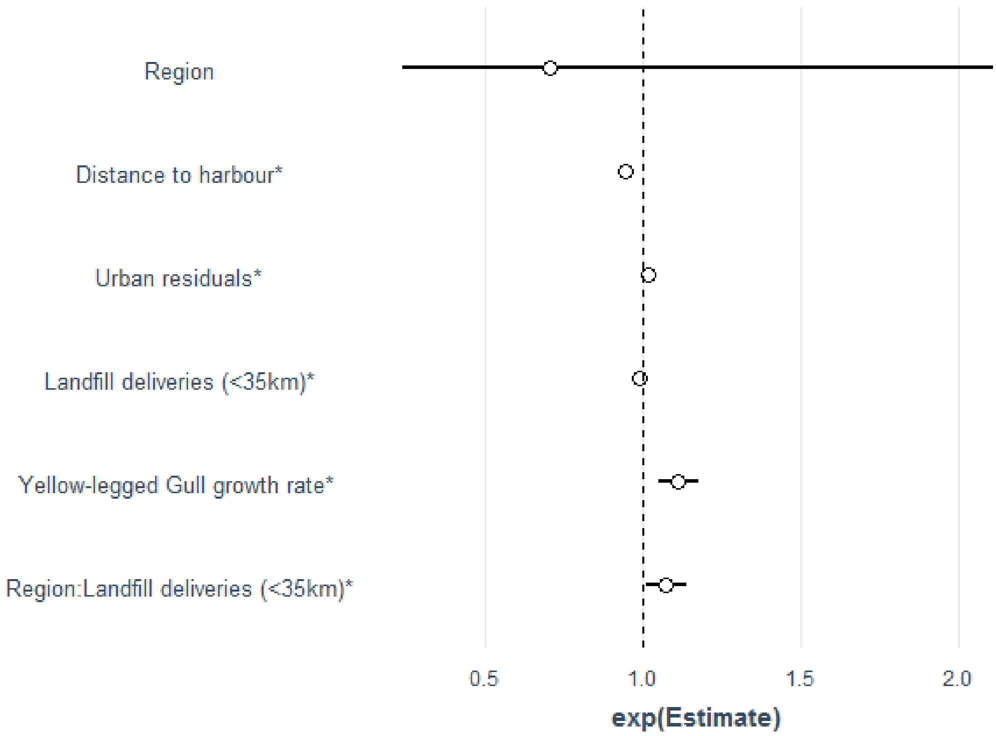
Table 2 - Results of the general linear model with negative binomial distribution used to evaluate the effect of anthropogenic food sources on the number of breeding pairs of Yellow-legged Gull (*Larus michahellis*) counted in Portugal in 2021. The sample size as the number of breeding sites (*n*) used in the model and the resulting Akaike Information Criterion (AIC) are depicted. AIC difference (ΔAIC) with the null model (Number of breeding pairs ~ 1) is also presented, as well as the amount of explained variability (Pseudo R^2). * highlights the variables with a significant effect ($p < 0.05$).

Tabela 2 - Resultado do modelo linear generalizado com distribuição binomial negativa usado para avaliar o efeito das fontes de alimento de origem antropogénica no número de casais reprodutores de gaivota-de-patas-amarelas (*Larus michahellis*) contadas em Portugal, em 2021. O tamanho da amostra dado como o número de locais de reprodução (*n*) usados no modelo e o resultado do Critério de Informação de Aikaike (AIC) são também mostrados. A diferença entre os valores de AIC (ΔAIC) do modelo usado e do modelo nulo (Número de casais reprodutores ~ 1) é também apresentada, bem como a quantidade de variabilidade explicada pelos modelos (Pseudo R^2). O * indica as variáveis com um efeito significativo ($p < 0.05$).

Variables	*n*	AIC	ΔAIC	Pseudo R^2
Number of breeding pairs ~ Region + Distance to harbour* + Urban residuals* + Landfill deliveries (<35km)* + Yellow-legged Gull growth rate* + Region: Landfill deliveries (<35km)*	45	461.99	0	0.63
Number of breeding pairs ~ 1	45	494.34	32.35	0.00

Figure 2 - Exponential coefficient estimates and standard errors for each variable of the selected model. The vertical slashed line [exp(Estimate) = 1] shows the limit of a positive or negative effect of a given variable, i.e. exponential estimate below 1 indicates a negative effect while estimates above 1 indicate a positive effect. The effect is lower as closer to the slashed line. Being region a categorical variable, Portugal mainland is used as baseline value. * highlights the variables with significant effect ($p < 0.05$).

Figura 2 - Exponencial das estimativas dos coeficientes e erros padrão para cada variável do modelo selecionado. A linha vertical a tracejado [exp(Estimate) = 1] mostra o limite a partir do qual uma variável apresenta um efeito positivo ou negativo, i.e. uma variável com um valor do exponencial da estimativa abaixo de 1 indica um efeito negativo, ao passo que valores acima de 1 indicam um efeito positivo. Quanto mais próximo da linha a tracejado, menor é a importância do efeito da variável. Tendo em conta que a região é uma variável categórica, Portugal continental é usado como valor de referência. O * indica as variáveis com efeito significativo ($p < 0.05$).



Discussion

Population size and distribution of breeding colonies

Here, we present a recent estimate of Yellow-legged Gulls breeding in Portugal and explore the potential explanations for the changes in terms of population size and breeding distribution observed during the last two decades. Overall, 7,350 – 8,000 breeding pairs were estimated to be currently breeding in Portugal.

On the mainland, Yellow-legged Gulls expanded their breeding range along the entire coast. It is noteworthy that in the beginning of the 21st century, the northern limit of the distribution of the Yellow-legged Gull breeding population was the Berlengas archipelago (Catry 2002, Morais et al. 2010), despite some anecdotal records of few birds breeding up north in Porto city and Vila Real (Equipa-Atlas 2008). The occupation of the northern half of the mainland began with the breeding in urban sites during the late 1990 (Morais and Casanova 2008). This might be mainly related to the absence of suitable natural habitat for reproduction (Catry 2002), which led to the occupation of urban sites, particularly in the main city and its surroundings, i.e. Porto, Vila Nova de Gaia and Matosinhos. A similar pattern was observed further north in the Iberian Peninsula, with the first gulls occupying the urban sites of Galicia by mid-1980 (Mouriño et al. 1999). Nowadays, Yellow-legged Gulls can be found on several different types of urban structures, e.g. building roofs, small bridges, terraces, balconies or on top of dead palm trees. Nesting gulls were also found in the main urban sites (cities and villages) spread along the whole coastline. Peniche and Lisbon were other two coastal cities with a recent occupation and a high increase in population size over the last few years (Bastos 2007, Mãe-D'Água 2017). The first records of breeding gulls in these cities date from 2002 and 2009/2010 in Peniche (Morais and Casanova 2008) and Lisbon (Mãe-D'Água 2017), respectively. Additionally, the species has shown an expansion of the breeding range towards south and southeast. In the end of the 1970s, no breeding was recorded along the eastern coast of the Algarve (Araújo and Rufino 1981), and only localized breeding attempts were reported for this area during the beginning of the 21st century, namely in wetlands and saltpans (Equipa-Atlas 2008). In contrast, Culatra and Barreta (also named as Deserta) islands (Ria Formosa, Faro) hold important colonies nowadays, accounting for 1% (N = 57) and 8-9% (N = 485) of the mainland population, respectively. These sandy islands provide a new type of habitat used by Yellow-legged Gulls in mainland Portugal, although this type of habitat is known to be used by this species in other areas (del Hoyo et al. 1992).

In terms of abundance and despite the increase in breeding range, Yellow-legged Gulls showed a smaller population (5,566 to 6,039 breeding pairs) in 2021 when compared with estimates from 2002, when 15,943 to 15,993 breeding pairs were estimated in Portugal mainland (Equipa-Atlas 2008). In 2002, the Berlenga Island population represented approximately 95% of the mainland population, which contrast with 40% in 2021. A population control programme implemented since 1995 at Berlengas (Morais et al. 2016) reduced the population to its current size. Despite this, Berlengas archipelago still harbours the largest population, followed by Pessegueiro Island and Porto urban area. The colony of Pessegueiro Island showed a steep increase, with 860-900 pairs in 2021 contrasting with the 175-200 pairs found in 2002 (Catry 2002) and the 500 pairs reported in 2017 (Calado et al. 2020b). In fact, after excluding Berlengas population from the analysis, the Yellow-legged Gull showed a 3-fold increase compared to the estimates made 20 years ago (943 to 993 breeding pairs; Catry 2002). Also, it is evident that the importance of urban populations has been steadily increasing over the last years. Nowadays, approximately 30% of the gull population in mainland Portugal is breeding in cities. A similar situation is observed in other areas of Iberia (SEO/BirdLife 2021) as well as in other parts of Europe (Nager and O'Hanlon 2016). The increase in urban populations, however, may not compensate the reduction of breeding pairs in natural habitats (Nager and O'Hanlon 2016).

In the case of the Azores, the breeding population has kept a stable breeding range, spread around all islands and the majority of the larger islets, although some changes were noted at a finer scale. However, the breeding population has occupied a greater area within the main islands than reported in the past (Neves et al. 2006), namely on Pico, Terceira and Santa Maria islands, where single pairs or small groups can be found along the entire coastline. In terms of abundance, and despite the limited coverage of this census (i.e. important colonies of São Jorge and Faial islands were not surveyed), the Azorean population is likely decreasing, when compared the 1,606-1,712 pairs estimated in this study to the 4,249 pairs estimated in 2004 (Neves et al. 2006). The same trend was found on all islands. The notable decrease of gull numbers in the largest historical colonies significantly contribute to this trend, namely the colonies on Cabras Islet (Terceira Island), Lagoa do Fogo (São Miguel Island) and Mistério da Prainha (Pico Island), where a decrease between 28 and 83% was recorded.

In the Madeira archipelago, Yellow-legged Gull nests were found in all locations where the species is historically known to breed. No counts were made on Selvagem Pequena (Selvagens archipelago), but no changes are expected due to the very small number of nests (6 - 7), low productivity (1 flying chick) and low numbers of non-breeding birds (1-2) found either in 2005 and 2010 (Catry et al. 2010). In terms of numbers, a steep decline was found, with an estimated population of 52-105 breeding pairs compared to the 3,969-3,973 breeding pairs estimated during the last counts performed between 2002 and 2010 (Fagundes et al. 2002, Catry et al. 2010, Matias and Catry 2010).

The effect of anthropogenic food sources

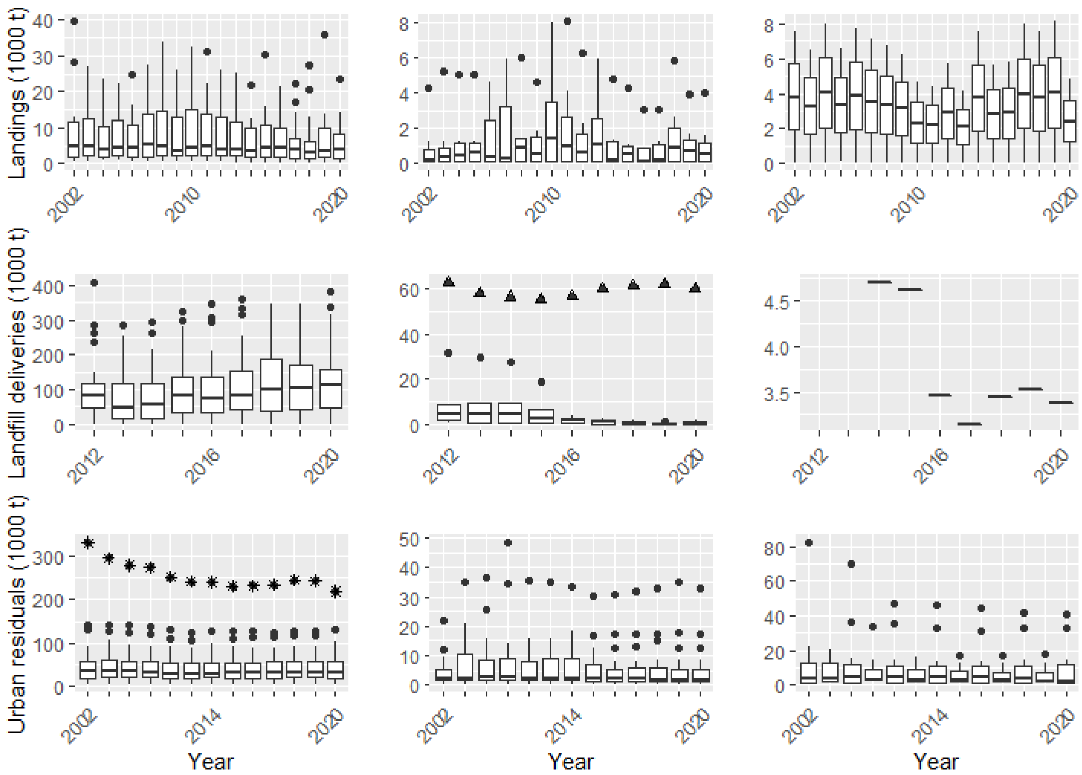
Yellow-legged Gulls are known to use several anthropogenic food sources, although variations during the course of the year and among populations occur (Calado et al. 2020b). Their opportunistic and generalist behaviour allows them to exploit easier sources of food. During the breeding season, while they are somewhat limited in terms of movement, gulls tend to use sources located in the vicinity of the colony (Ceia et al. 2014, Matos et al. 2018). For these reasons, changes in food availability close to breeding colonies are expected to have an effect on gull numbers (Furness 2003).

Seafood from commercial fisheries represents an important intake for gulls (Neves et al. 2006, Romero et al. 2019, Lopes et al. 2021). Even populations with a high dependence on refuse during the entire year showed a shift in their diets towards seafood while feeding their chicks (Lopes et al. 2021). Ours results revealed that colonies located near fishing harbours have higher numbers of breeding pairs than those located far away, regardless of differences in the annual weight of seafood catch among harbours. The general slight decrease in the fishing effort and amount of fish caught in the continental waters during the last 20 years (Bueno-Pardo et al. 2020), seems to be insufficient to prevent the gull population increment in terms of both distribution and population size. Such a decrease is less noted in terms of trawling activity, which is by far the type of fishery responsible for the largest amount of fish discards and which produces the biggest portion of seafood supplements for gulls (Kelleher 2005). Trawls discard nearly 74% of the catch (Louzao et al. 2011), which may explain the great amount of demersal fish in Yellow-legged gull diet (Ceia et al. 2014, Matos et al. 2018, Calado et al. 2020a). However, the importance of purse seine activity as source of seafood supplements for gulls cannot be neglected. In areas where purse seine activity is higher, gulls tend to attend purse seiners in greater number and frequency, feeding from both catch and discards (Calado et al. 2020a), which may be of particular importance during years of low availability of most common prey, as observed by their diet (Alonso et al. 2015). In the case of the archipelagos, there are no trawls operating in the area and only three purse seiners fish in Madeiran waters (INE 2020), resulting in a smaller catch size compared to the mainland (Fig. 3), which might explain the lower dependence on fisheries-related waste by local Yellow-legged Gull populations (Neves et al. 2006, Pedro et al. 2013).

Refuse is available to gulls in landfills and other structures used along the residue management chain.

Figure 3 - Trends in the annual weight of fish landings (top row), residues dumped in landfills (centre row) and non-differentiated residues collected (bottom row) in Portugal mainland (left column) and the archipelagos of the Azores (centre column) and Madeira (right column). * highlights the non-differentiated residues collected in Lisbon municipality, while black triangles show the residues dumped on São Miguel Island, both clearly above the mean of the weight found in the remaining locations.

Figura 3 - Tendências no peso anual de pescado descarregado nos portos de pesca (linha superior), resíduos depositados em aterro (linha central) e resíduos não diferenciados recolhidos (linha superior) em Portugal continental (coluna à esquerda) e nos arquipélagos dos Açores (coluna ao centro) e da Madeira (coluna à direita). O * indica os resíduos não diferenciados recolhidos no município de Lisboa, enquanto que os triângulos a preto mostram os resíduos depositados em aterro na ilha de São Miguel, ambos claramente acima da média calculada para as restantes localizações.



Here, we used several measures to assess the effect of refuse on Yellow-legged Gull population size. Numbers of breeding gulls were higher in sites with greater supplies of urban waste received by the municipality. Yellow-legged gulls have been recorded to feed in urban areas from different types of structures, including garbage bins, at restaurant promenades, and stealing food from people in the street (Pais de Faria et al. 2021). Gulls' feeding by citizens is also an important food supplement for urban gulls, which is found later in the analysis of gull diets (see e.g. Lopes et al. 2020). Pais de Faria et al. (2021) found that approximately 60% of the events of gulls interacting with humans or human activities in urban environments were usually related with food intentionally provided by people, contrasting with 21% of events of birds attracted to regular food structures, 14% on gulls stealing/prowling humans for food and 5% foraging on trash. On the other hand, our results suggest that sites with a lower weight of residues delivered to the landfills near the nest sites (<35 km apart) have a higher number of nesting gulls. This relationship may suggest that food availability at the landfills might be more related to specific management measures implemented at the landfills rather than the total amount of residues delivered alone. Each landfill is managed at the local level by a specific company, which may own a contract to manage a single facility or a group of a few facilities located in the same district. At a regional scale there is an effort to establish common management programmes, that may include measures to reduce the time and area that residues are left in the open air before it is covered, although there is still wide variation between landfills. Some facilities have extensive active areas that are kept open for several months, i.e. areas where refuses are deposited without being covered, while others have small areas that are covered in a weekly basis (Nuno Oliveira pers. obs.). In addition, landfill management in Portugal is subject to the rules established by the European Commission Directives on Landfill (Council Directive 1999/31/EC) and Waste Framework (Directive 2008/98/EC), which set out strict operational requirements for landfills with the aim of protecting human health and the environment. However, no details are given regarding the limits on the size of active depositing area or the time and duration of depositing, and there are no requirements to avoid food availability for wildlife.

Nevertheless, at a larger scale, landfills are the structures where most refuse is gathered and Yellow-legged Gulls are known to visit these facilities at different stages of their life cycle, either during the breeding (Ceia et al. 2014, Matos et al. 2018) or non-breeding seasons (Silva 2021). In addition, previous studies have documented several responses of gulls after the closure of landfills. Birds are forced to change habitat selection, to travel longer distances resulting in higher foraging costs (Langley et al. 2021), and to shift their diet (Zorrozua et al. 2020), which can lead to a decline in body condition and breeding fitness (Steigerwald et al. 2015). However, an effect on other demographic parameters, e.g. survival, might be less likely due to their long-living life-history strategy, which means that populations change relatively slowly over time (Oro et al. 2004). On the other hand, our results showed a sharp decline of the breeding population of Madeira archipelago and for some breeding colonies in Azores, which might be related with the reduction in landfill deliveries, following the improvement of landfill management and the closure of several small open-air refuse dumps during the last decade, which, combined with a reduced availability of fisheries-related food supplements, could accelerate the effect of a reduction in anthropogenic food on gull numbers. In fact, all Azorean landfills except on Terceira and São Miguel islands were recently shut down, as well as the one on Porto Santo Island, Madeira. Madeiran and Azorean populations show a high dependence on refuse likely gathered from local landfills or dumps (Neves et al. 2006, Romero et al. 2019). Fish items gathered from local fishing fleets, usually from fishery offal or discards, play a very negligible role. The absence of a trawling fishing fleet operating in the area together with very few vessels operating purse seines, the gears responsible for larger amounts of discards and most intensively used by gulls to fed on (Calado et al. 2020a), may explain the low importance of fisheries subsidies for these gull populations. Although chicks are still mainly fed on marine prey (Romero et al. 2019), these populations have been shown to be highly dependent on subsidies gathered from landfills and other refuse sources, which could explain the sharp decline in the number of breeding pairs. Nevertheless, censuses should be carried out in the near future in order to evaluate and confirm the decline of the breeding population size.

Recommendations for future management

Yellow-legged Gulls are among the group of gulls that are often found to be superabundant due to their adaptability, opportunistic and gregarious nature, which predisposes them to live in human modified habitats (Ceia et al. 2014, Alonso et al. 2015, Calado et al. 2020b). In recent decades, several environmental problems caused by superabundant animal species, in particularly by large gulls, have been raised. The negative impact on vertebrate fauna is one of the most frequently mentioned problems, especially on seabirds breeding in sympatry. This impact can include depredation (Martínez-abraín et al. 2003, Catry et al. 2010, Matias and Catry 2010, Pedro et al. 2013) or direct competition for breeding and feeding sites (Perennou et al. 1996). Negative impacts on vegetation and soil at nesting sites are also well documented (Vidal et al. 1998, De La Peña-Lastra et al. 2021, Peña-Lastra et al. 2022).

Reducing the availability of food from anthropogenic sources has impacts on the productivity and demographic structure of gulls (Steigerwald et al. 2015). This study brought important insights on the effects of fisheries and urban residues on the size and distribution of Yellow-legged Gull populations in Portugal. An improvement of the management of fish discards and waste in order to reduce such food supplements could help to balance the unregulated growing of gull populations both in natural and urban environments. Changes in refuse management (e.g. by reducing the exposed landing area or falconry) are costly and may be logistically challenging to implement (Thomas 1972). However, after being in place, no further increase in costs is expected (Slate et al. 2000). On the other hand, improvements of refuse management will also contribute to the regulation of other populations in similar situations, either native (e.g. White Stork *Ciconia ciconia*), exotic/invasive (e.g. Brown Rat *Rattus norvegicus*) or domestic species (e.g. feral pigeon *Columba livia domestica*; Plaza and Lambertucci 2017).

There are some examples of the effect of landfill closure on Yellow-legged Gulls (Zorrozua et al. 2020, Langley et al. 2021). The closure of landfills by itself may bring public health issues, but the improvement of landfill management should at least include the reduction of the exposed refuse area or the use of deterrents in order to limit the access to wild animals (Cook et al. 2008). At urban sites, public policies regarding waste management may include the use of street containers with automatic lids in a proper number (Coccon et al. 2021). Also, it is recommended to avoid placing garbage bags in front of buildings for later collection (Pais de Faria et al. 2021). Awareness campaigns and law enforcement with respect to the feeding of wild or domestic animals in the street are another important way to reduce food availability for gulls and other species (e.g. feral pigeons). Finally, the reduction of fishery discards, simple modifications in offal management (e.g. throw it away "all at once" instead of doing it continuously while cleaning the catch), avoiding active feeding of gulls by fishermen and the use of deterring devices to prevent gulls from feeding on fish remnants (Oliveira et al. 2021) will significantly reduce food availability for gulls.

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